Appendix D - Fire and Fuels

The following is a description of the components and the process involved in determining fuel models, fire behavior potential, and risk for the Horse Creek watershed analysis.

Fuel Model Definitions

The prediction of fire behavior is valuable for assessing potential fire damage to resources, for fire suppression pre-planning, and for fuels treatment planning and implementation. A quantitative basis for rating fire danger and predicting fire behavior became possible with the development of mathematical fire behavior fuel models. Fuel modeling and the Prediction of fire behavior has been a valuable tool for analysis and project implementation on the Klamath National Forest. These tools have been utilized and refined on the Klamath National Forest for nearly 30 years.

Fuels have been classified into four groups; **grasses, shrubs, timber,** and **slash**. The differences in these groups are related to the fuel load and distribution of fuel among size classes. Size classes are: 0 - ¼" (1 hour fuels); ¼" – 1" (10 hour fuels); 1" - 3" (100 hour fuels); and 3" and greater (1,000 hour fuels).

The criteria for choosing a fuel model (Anderson 1982) includes the fact that fire burns in the fuel stratum best conditioned to support fire. Fuel models are simply tools to help the user realistically estimate fire behavior. Modifications to fuel models are possible by changes in the live/ dead ratios, moisture contents, fuel loads, and drought influences.

A description of fuel models used in fire behavior as documented by Albini (1976) is summarized in **Table D-1**, *Albini Fuel Models*. A brief description of each of the 13 fire behavior fuel models follows.

Table D-1. Albini Fuel Models

FUEL MODEL Typical Fuel Complex	FUEL LOADING tons/acre				Fuel Bed Depth feet
	1Hr.	10 Hr.	100 Hr.	Live	
Grass and Grass-Dominated					
1-Short Grass (1ft)	0.74	0.00	0.00	0.00	1.0
2-Timber (Grass and Understory)	2.00	1.00	0.50	0.50	1.0
3-Tall Grass (2.5ft.)	3.01	0.00	0.00	0.00	2.5
Chaparral and Shrub Fields					
4-Chaparral (6ft)	5.01	4.01	2.00	5.01	6.0
5-Brush (2ft)	1.00	0.50	0.00	2.00	2.0
6-Dormant Shrub & Hdwd. Slash	1.50	2.50	2.00	0.00	2.5
7-Southern Rough	1.13	1.87	1.50	0.37	2.5
Timber Litter					
8-Closed Timber Litter	1.50	1.00	2.50	0.00	0.2
9-Hardwood Litter	2.92	0.41	0.15	0.00	0.2
10-Timber (Litter and Understory)	3.01	2.00	5.01	2.00	1.0
SLASH					
11-Light Logging Slash	1.50	4.51	5.51	0.00	1.0
12-Medium Logging Slash	4.01	14.03	16.53	0.00	2.3
13-Heavy Logging Slash	7.01	23.04	28.05	0.00	3.0

GRASS GROUP

Fire Behavior Fuel Model 1 - Fire spread is governed by the very fine, porous, and continuous herbaceous fuels that have cured or are nearly cured. Fires are surface fires that move rapidly through the cured grass. Very little timber or shrub is present.

Fire Behavior Fuel Model 2 - Fire spread is primarily through cured or nearly cured grass where timber or shrubs cover one to two-thirds of the open area. These are surface fires that may increase in intensity as they hit pockets of other litter.

Fire Behavior Fuel Model 3 - Fires in this grass group display the highest rates of spread and fire intensity under the influence of wind. Approximately one-third or more of the stand is dead or nearly dead.

SHRUB GROUP

Fire Behavior Fuel Model 4 - Fire intensity and fast spreading fires involve the foliage and live and dead fine woody material in the crowns of a nearly continuous secondary overstory. Stands of mature shrubs, six feet tall or more are typical candidates. Besides flammable foliage, dead woody material in the stands contributes significantly to the fire intensity. A deep litter layer may also hamper suppression efforts.

Fire Behavior Fuel Model 5 - Fire is generally carried by surface fuels that are made up of litter cast by the shrubs and grasses or forbs in the understory. Fires are generally not very intense because the fuels are light and shrubs are young with little dead material. Young green stands with little dead wood would qualify.

Fire Behavior Fuel Model 6 - Fires carry through the shrub layer where the foliage is more flammable than fuel model 5, but requires moderate winds, greater than eight miles per hour.

Fire Behavior Fuel Model 7 - Fires burn through the surface and shrub strata with equal ease and can occur at higher dead fuel moistures because of the flammability of live foliage and other live material.

TIMBER GROUP

Fire Behavior Fuel Model 8 - Slow burning ground fuels with low flame lengths are generally the case, although the fire may encounter small "jackpots" of heavier concentrations of fuels that can flare up. Only under severe weather conditions do the fuels pose a threat. Closed canopy stands of short-needled conifers or hardwoods that have leafed out support fire in the compact litter layer. This layer is mostly twigs, needles, and leaves.

Fire Behavior Fuel Model 9 - Fires run through the surface faster than in fuel model 8 and have a longer flame length. Both long-needle pine and hardwood stands are typical. Concentrations of dead, down woody material will cause possible torching, spotting, and crowning of trees.

Fire Behavior Fuel Model 10 - Fires burn in the surface and ground fuels with greater intensity than the other timber litter types. A result of overmaturing and natural events creates a large load of heavy down, dead material on the forest floor. Crowning out, spotting, and torching of individual trees is more likely to occur, leading to potential fire control difficulties.

SLASH GROUP

Fire Behavior Fuel Model 11 - Fires are fairly active in the slash and herbaceous material intermixed with the slash. Fuel loads are light and often shaded. Light partial cuts or thinning operations in conifer or hardwood stands. Regeneration harvest operations generally produce more slash than is typical of this fuel model.

Fire Behavior Fuel Model 12 - Rapidly spreading fires with high intensities capable of generating firebrands can occur. When fire starts it is generally sustained until a fuelbreak or change in conditions occur. Fuels generally total less than 35 tons per acre and are well distributed. Heavily thinned conifer stands, regeneration units, and medium to heavy partial cuts are of this model.

Fire Behavior Fuel Model 13 - Fire is generally carried by a continuous layer of slash. Large quantities of material three inches and greater is present. Fires spread quickly through the fine fuels and intensity builds up as the large fuels begin burning. Active flaming is present for a sustained period of time and firebrands may be generated. This contributes to spotting as weather conditions become more severe. Regeneration units are depicted where the slash load is dominated by the greater than three inch fuel size, but may also be represented by a "red slash" type where the needles are still attached because of high intensity of the fuel type.

In addition to the standard fuel models, this analysis has done some non-standard labeling to identify fuel models that are present due to management activities and some areas that are naturally less sensitive to fire disturbance. Fuel models identified and used in this analysis are listed and described in **Table D-2** *Horse Creek Fuel Models*. Further discussion of the non-standard models follows.

Table D-2. Horse Creek Fuel Models

Fuel Model	Acres	Fuel Model Description
2	4,245	Cured light grass is primary carrier of fire. Mostly found within the oak woodlands vegetation community.
2C	1,825	Fuel model 2 conditions that are currently found in young plantations (0 to 10 years old).
5	935	Montane chaparral
5C	5,324	Fuel model 5 conditions that exist in plantations that are 10 to 20 years old.
6	2,958	Montane chaparral w/decadence
6C	1,822	Fuel model 6 conditions that exist in plantations >20 years old.
8	6,060	Typically mature true fir dominated stands with open understories and low fuel accumulations
9	11,548	Typically these are pine dominated stands with open understories
10	28,508	Typically these are multi-layered conifer dominated stands with dense understories and high fuel accumulations
11	2,530	These are typically recent partial cut units.
12	826	Heavily thinned conifer stands, regeneration units, and medium to heavy partial cuts.
14	1,478	These are riparian shrub and montane meadow vegetation types that typically burn with low intensity except during drought conditions.
0	870	Non-flammable material, i.e., gravel bars, rock outcroppings, and barren areas.
Ag	850	Agricultural lands in the Horse Creek drainage and along the Klamath River. These areas may become flammable when not irrigated or grazed.

Fire Behavior Fuel Model 2C has been generated to represent fuel model 2 conditions that are currently found in young plantations (0 to 10 years old).

Fire Behavior Fuel Model 5C has been generated to represent fuel model 5 conditions that exist in plantations that are 10 to 20 years old.

Fire Behavior Fuel Model 6C has been generated to represent fuel model 6 conditions that exist in plantations >20 years old.

Fire Behavior Fuel Model 14 has been generated to represent conditions that under typical 90th percentile weather conditions, burn patchy and with low intensity, typical of wet meadows and riparian vegetation. These areas can also experience uniform moderate to high intensity burning during drought.

Weather Data

The 90th percentile weather data is based on twenty years of data collected at Oak Knoll for elevations less than 4,000 feet and Collins Baldy for elevations greater than 4,000 feet. These weather stations are both within the analysis area and have at least 20 years of weather data. Weather files from 1980 through 1999 were looked at in the Fire Family Plus program to identify 90th percentile values in the following table.

Table D-3. 90th Percentile Fuel Moisture

90th percentile values used for fire behavior calculations	Oak Knoll Weather Station	Collins Baldy Weather Station
1 Hour fm	3	4
10 Hour fm	4	5
100 Hour fm	9	6
1000 Hour fm	11	8
Live Woody fm	70	50
Herbaceous fm	<30 (5)	30
20 Foot Wind Speed	7 mph	9 mph
fm = fuel moisture		

Fire Behavior Potential

To determine Fire Behavior Potential Classes, each fuel model is run through the BEHAVE program. This program uses fuel model, slope, and weather parameters to predict fire behavior and resistance to control for fire suppression purposes. The 90th percentile weather from the most representative weather stations was used to model late summer afternoons, typical of late July through early September.

Three slope classes are used, consistent with the slope classes used in the LMP geologic hazard classification (0-34%, 35-65%, and greater than 65%). All fuel models were run through each of the three slope classes, to determine increases in fire behavior with increased steepness of terrain.

The output of this is a rating of Low, Moderate, or High fire behavior based on flame lengths, which are good indicators of fire line intensity and resistance to control, and/or rate of spread (ROS), which is also a good indicator of resistance to control.

Fire behavior potential modeling is done in order to estimate the severity and resistance to control that can be expected, when a fire occurs during what is considered the worst case weather conditions. Late summer weather conditions are referred to as the 90th percentile weather data, which is a standard used when calculating fire behavior (90th percentile weather is defined as the severest 10% of the historical fire weather, i.e., hot, dry, windy conditions occurring on mid afternoons during the fire season).
The modeling incorporates fuel condition, slope class, and 90th percentile weather conditions in calculating projections on flame lengths and rates of spread. A **low** rating indicates that fires can be attacked and controlled directly by ground crews building fire line and will be limited to burning in understory vegetation. A **moderate** rating indicates that hand built fire lines alone would not be sufficient in controlling fires and that heavy equipment and retardant drops would be more effective. Areas rated as **high** represent the most hazardous conditions in which serious control problems would occur i.e., torching, crowning, and spotting, control lines are established well in advance of flaming fronts with heavy equipment and backfiring may be necessary to widen control lines.

Using the CONTAIN model of BEHAVE, it was determined whether or not a fire with Low Flame Lengths could be contained by the initial attack forces. These runs indicated that given, typical response times, terrain, fuels, and available forces, a Low rating had to have a ROS less than 30 chains per hour, for containment to be accomplished during initial attack.

Fire Behavior Potential Classes

Low- Flame lengths less than 4' and ROS less than30chs/hr:
Fires can generally be attacked at the head or flanks by firefighters using hand tools. Landline should hold the fire.

Moderate- Flame lengths 4-8':
Fires are too intense for direct attack at the head of the fire by firefighters using hand tools. Hand line cannot be relied on to hold the fire. Equipment such as dozers, engines, water and/or retardant dropping aircraft can be effective.

High- Flame lengths greater than 8':
Fires may present serious control problems, such as torching, crowning, and spotting. Control efforts at the head of the fire will be ineffective.

Table D-4. Fuel Model / Fire Behavior Potential Crosswalk

Fuel Model	Aspect	Elevation	Slope	Fire Behavior Potential Rating
2 & 2C	ALL	<4000	<35%	MODERATE
2 & 2C	ALL	<4000	>35%	HIGH
2 & 2C	S&W	>4000	<35%	MODERATE
2 & 2C	S&W	>4000	>35%	HIGH
2 & 2C	N&E	>4000	<35%	LOW
2 & 2C	N&E	>4000	>35%	MODERATE
5 & 5C	S&W	<4000	<35%	MODERATE
5 & 5C	S&W	<4000	>35%	HIGH
5 & 5C	N&E	<4000	ALL	MODERATE
5 & 5C	ALL	>4000	ALL	MODERATE
6 & 6C	ALL	ALL	<35%	MODERATE
6 & 6C	ALL	ALL	>35%	HIGH
8	ALL	ALL	ALL	LOW
9	S&W	ALL	<65%	LOW
9	S&W	ALL	>65%	MODERATE
9	N&E	ALL	ALL	LOW
10	N	<4000	<35%	LOW
10	N	<4000	35-65%	MODERATE
10	S&W&E	<4000	<65%	MODERATE
10	ALL	<4000	>65%	HIGH
10	S&W	>4000	<65%	MODERATE
10	ALL	>4000	>65%	HIGH
10	N&E	>4000	<35%	LOW
10	N&E	>4000	35-65%	MODERATE
11	ALL	ALL	<65%	MODERATE
11	ALL	ALL	>65%	HIGH
12	ALL	ALL	ALL	HIGH
14	ALL	ALL	ALL	LOW
AG	ALL	ALL	ALL	LOW
0 & U	ALL	ALL	ALL	MOSTLY NON-FLAMMABLE

Using the crosswalk displayed in **Table D-4** *Fuel Model/ Fire Behavior Potential Crosswalk* the following acreages in each Fire Behavior Potential class was determined for the analysis area.

High- 6,926 acres (10% of the analysis area)
Moderate- 39,049 acres (56% of the analysis area)
Low- 22,886 acres (33% of the analysis area)
Non-flammable- 975 acres (1% of the analysis area)

Fire Risk

Historical records indicate lightning and human caused fires have been common in the watershed. Little precipitation (May to September) and high summer temperatures allow fuels to dry, which allows for ease of ignition and spread of wildfire.

There are numerous fire risks within the watershed. Many year-round residences, industrial endeavors, many dispersed camp sites, recreational use, power lines, and travel corridors all contribute to the possibility of a wildfire occurrence from human causes. However, The greatest risk of fire starts is from the occurrence of lightning. Thunderstorms are common throughout the summer months in and near the watershed. Lightning, erratic winds and usually precipitation accompany these storms. The latter limits the number of ignitions.

The Klamath National Forest fire history database indicates that within the watershed boundary 634 fire starts have occurred during the period from 1922-2000. Using this information and the vegetative composition the general fire risk assessment is determined for the analysis area. It is important to realize that risk is not the probability of a fire occurring, but the probability of when a fire will occur. In this analysis area, fire **will** occur.

A mathematical formula is used to derive a risk value. Included in the formula are the number of starts, number of years of historical information, and number of acres involved. The values in the formula are:

x =Number of starts recorded for the area from the fire start data base (634).
y = Period of time covered by the data base (for this analysis, 79 years).
z = Number of acres analyzed (displayed in thousands 69,936 = 69.9).
{(x/y)10}/z = Risk rating
{(634/79)10}/69.9 = 1.15

The value derived corresponds to a likelihood of fire starts per 1,000 acres per decade. The following are the risk ratings and range of values used to determine the risk.

Low Risk = 0-0.49: This projects one fire every 20 or more years per thousand acres.

Moderate Risk = 0.5-0.99: This projects one fire every 11-20 years per thousand acres.

High Risk = greater than or equal to 1.0: This level projects one fire every in 0-10 years per thousand acres.

The rating of 1.15 indicates that that this analysis area is a high risk for fire starts.

Using statistics from the fire history database, an average of eight fires occur within the analysis area each year. There is a .44 probability that a fire >40 acres will occur in any given year or an average of one every other year.

Fuels Treatment

Utilizing the Fuels Out-Year Request and Budget System (FORBS) program, fuels treatments completed in this analysis area show a high net benefit. By spreading out the *Forest Plan* fuels treatment objectives over the Forest's land base, the expectation would be to treat 638 acres per year within the analysis area. If the area were treated at a cost of $250/acre, a net benefit of $2,758/acre would be realized. This equates to an annual project cost of $159,500 and a resulting net benefit of $1,759,604.